RESEARCH DEPARTMENT

U.H.F. transmitters for site test use

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THE BRITISH BROADCASTING CORPORATION
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U.H.F. TRANSMITTERS FOR SITE TEST USE

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U.H.F. TRANSMITTERS FOR SITE TEST USE

SUMMARY

This report describes lightweight 7 to 10 W c.w. transmitters and control units for use during site tests in Band IV and V. The transmitters are designed for use on either a balloon or mast.

1. INTRODUCTION

In order to carry out a u.h.f. site test it is necessary to radiate a signal from an aerial on an existing mast or, in the case of a new site, on either a temporary low mast or a balloon.

It is convenient to use the same transmitter for all tests but the restricted lift of the balloon places a severe weight limit on the transmitter and hence power output. In practice the balloon may have to fly at heights of up to 370 m and, after allowing for the weight of the tethering cable, a payload of only about 6½ kg is possible. Of this payload, 1 kg is required for the superturnstile aerial leaving 5½ kg for the transmitter.

The coaxial tethering cable which has to have a breaking strain of 10^4 Newtons and which must also carry the power (at 700 Hz) for the transmitter, has a stainless steel outer armouring and in consequence a considerable loop resistance (about 150 ohms). The voltage drop in the cable and changes in supply voltage are compensated by a simple servo system which adjusts the voltage applied to the cable in response to signals sent from the transmitter. This feature is of particular value as it permits the transmitter to be used with any length or type of cable, within limits, without having to absorb considerable power in the final stabilizer in the transmitter unit. The power supply has a frequency of 700 Hz in order to reduce the weight of the power transformer in the transmitter, and the supply is provided in the ground control unit at a voltage of up to 200V.

Since power is being fed to the balloon winch it is necessary to ensure the safety of the operator. This is done by monitoring the continuity of the earth return from the control unit through the winch slip rings to the balloon cable. If continuity is lost a trip relay operates and removes power from the winch. The operation of the trip relay is normally checked by an automatic marker which interrupts the supplies for two seconds every minute as an identification signal. An emergency switch is provided on the balloon winch to enable the operator to disconnect the supplies to the transmitter at any time.

The provision of transmitters and receivers is simplified by the use of only three frequencies, one (522 MHz) in Band IV and two (666 and 756 MHz) in Band V, and employing a measuring technique for which c.w. transmitters are suitable.[1] The frequencies were chosen to be near the centre of each of the three groups of frequencies into which the u.h.f. bands are divided. A frequency tolerance of a few kilohertz must be observed.

The transmitters consist of a v.h.f. crystal oscillator, mounted in an oven for frequency stability, followed by a power amplifier and varactor frequency doubler.[2] This is followed by three stages of power amplification to give an output power of 20 W to 25 W at a frequency of about 100 MHz. A varactor tripler and doubler follow this amplifier giving 7 W to 10 W output, dependent on frequency.

2. THE CONTROL UNIT

A circuit diagram of the ground control unit is given in Fig. 1. The mains input is applied to the transformer T2 via a motor driven variable transformer T1 which has an operating range of about 80 V. The rectified and smoothed output from T2 supplies the 700 Hz square-wave oscillator TR3, TR4. The output voltage of this oscillator is stepped up to 140V to 200V, depending on the setting of the switch S8A, thus allowing cables with loop resistances of up to 150 ohms to be used between the control unit and the transmitter.

On switching on, mains is applied to the variable transformer drive motor via the relay contact RLA2. This causes the motor to drive the transformer until the minimum output voltage is reached.

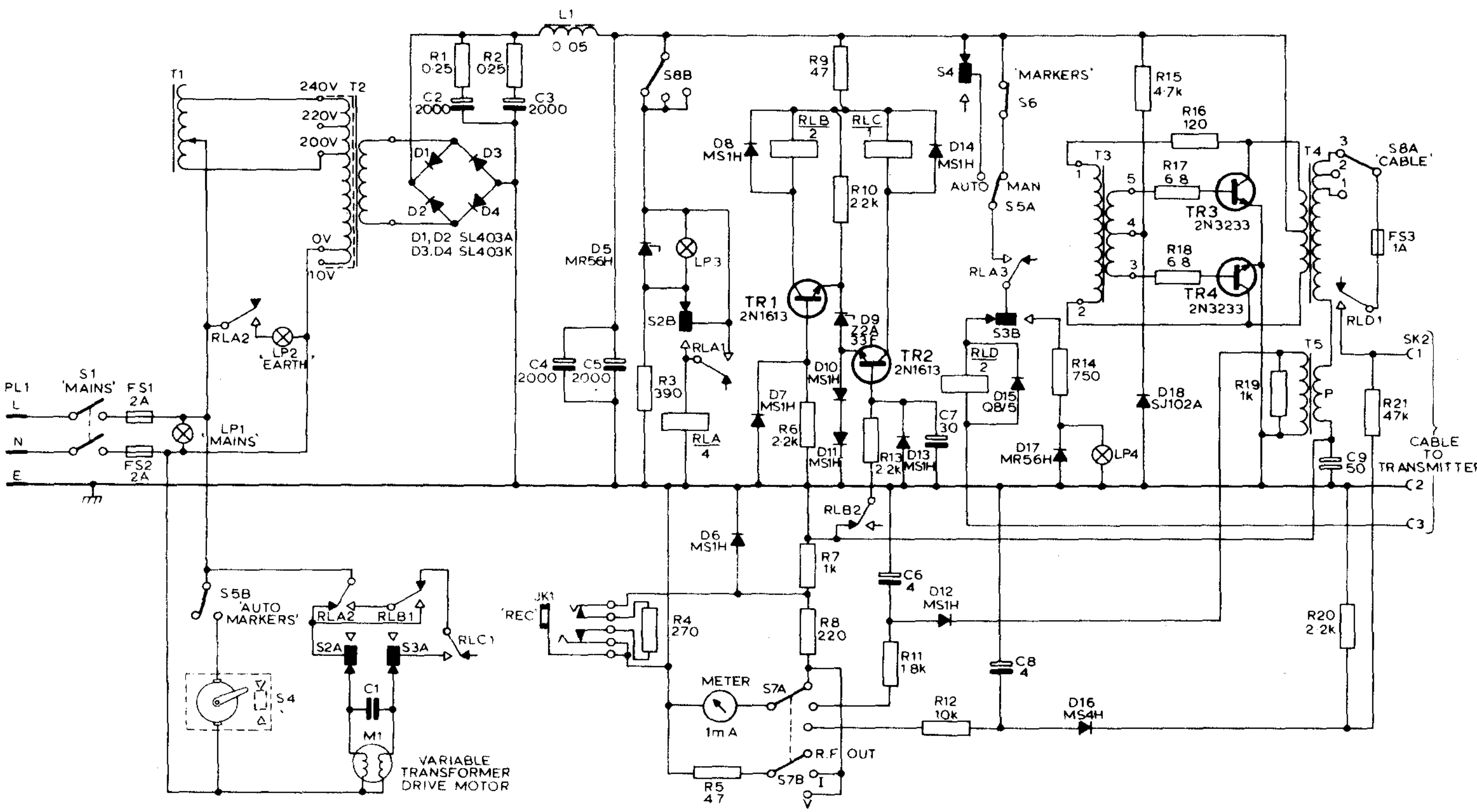


Fig. 1 - The ground control unit for the u.h.f. transmitter

The limit switch S2B then closes permitting RLA to operate and lock on. This applies power to one side of relay RLD. If there is continuity between the other side of this relay and earth, i.e. pin 2 of SK2 (right hand side of Fig. 1) is earthed via the balloon winch and cable outer, then relay RLD will operate and feed power to the balloon cable via contact RLD1. When the transmitter is used attached to a mast, a three-core cable is used and the earth continuity is checked as far as the transmitter input socket. The output from the control unit is removed if the supply to relay RLD is interrupted by either the manual (S6) or automatic (S4) marker switches, or by the limit switch S3. The automatic marker switch is operated by a two-second cam on a 1 r.p.m. synchronous motor. The return path for the 700 Hz current to the transmitter is via a current transformer T5 and bypass capacitor C9; this allows the output current to be metered. Provision is also made for monitoring the output voltage.

Certain d.c. voltages produced in the transmitter unit are applied to the inner of the cable and appear at terminal 1 of the socket SK2 (right hand side of Fig. 1) from which point they are switched by diodes D6, D13 or D7 to the meter if negative or to TR1 or TR2 if positive. The negative voltage which is normally fed to the cable, is produced by the power-monitor diode (D25, Fig. 3) and will operate either the meter or an external recording milliammeter. If the power supply voltage at the transmitter is incorrect, however, positive voltages will be applied to the cable (see section 3) to operate either relay RLB or RLC. These cause the motor driven variable transformer to take corrective action depending on whether the voltage is too high or too low. Limit switches are fitted to the variable transformer T1 and operate warning lights LP3 or LP4. The high limit switch S3 also causes relay RLD to open, thus removing the power supplies from the transmitter. If the main supply is interrupted or if the cable switch S8 is operated causing a break in continuity by switch S8b, then relay RLA is released and the whole starting process is repeated.

3. TRANSMITTER POWER SUPPLY

A circuit diagram of the power supply system in the transmitter unit is shown in Fig. 2.

The input transformer T1 supplies a bridge rectifier D1 to D4 giving an unstabilized d.c. output at about 36V. A large capacitor C1 in series with the primary of this transformer permits d.c. to be applied for monitoring and control as already described. There are three Zener diodes D5 to D7 in series across the unstabilized supply. The diode D7 is shunted so that it only conducts when there is excessive input from the control unit. In this condition the three diodes conduct heavily and either blow the control unit fuse or stop the power oscillator by overload, a safe condition. In normal operation, if the voltage across D7 is less than 1·8V then the transistors TR7 and TR8 will be cut-off and + 3V applied to the balloon cable. This causes the control unit to raise the supply voltage. When the voltage across D7 rises above + 2V TR8 conducts and operates relay RLB. This removes the + 3V from the balloon cable and applies the power-monitoring voltage. If the mains supply should change, raising the voltage across diode D7 to more than 4V, then transistor TR7 will conduct and operate relay RLA which will connect + 6V to the balloon cable. This causes the control unit to reduce its output until it is again within the required operating range.

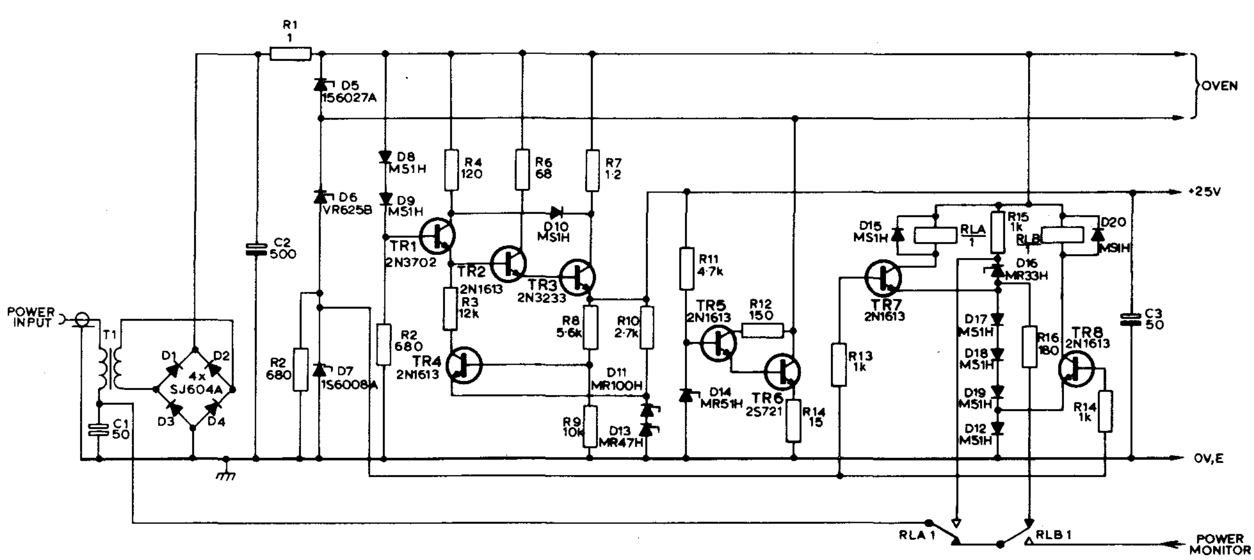


Fig. 2 - The u.h.f. transmitter power supply unit

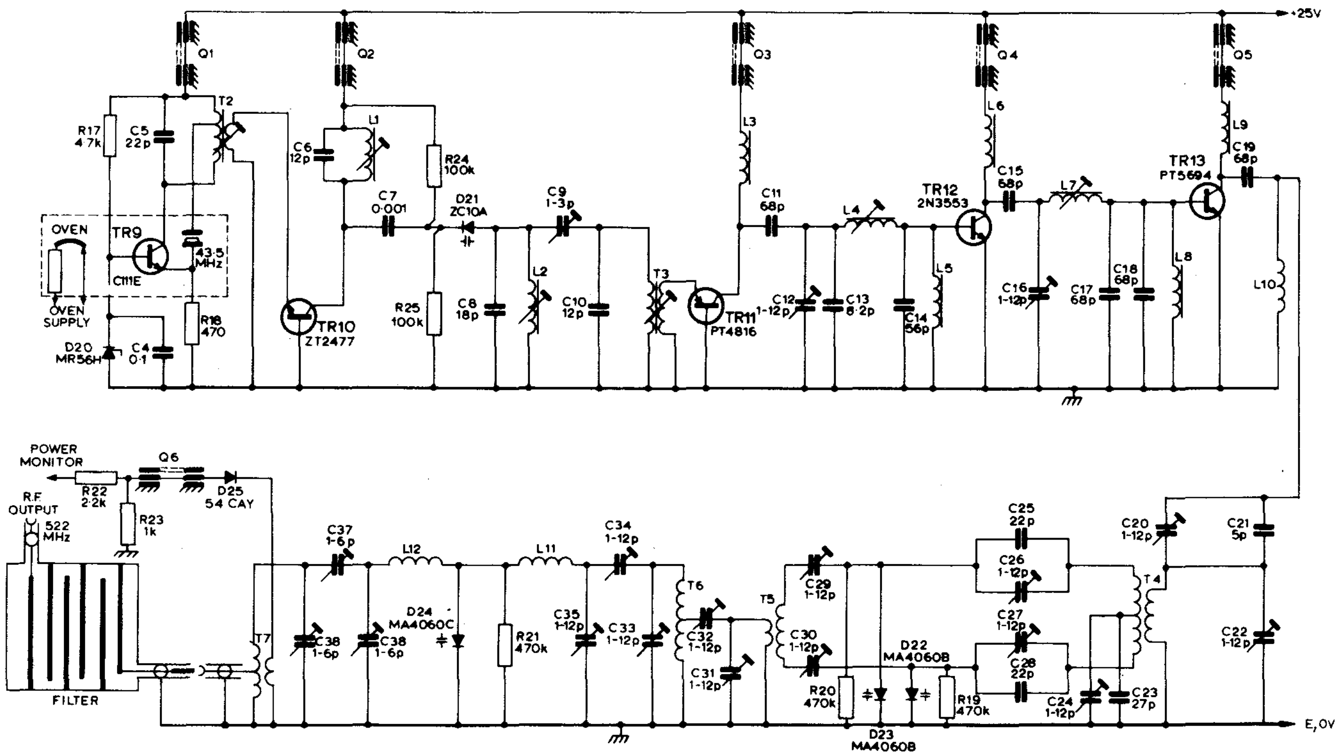


Fig. 3 - The 522 MHz transmitter

The unstabilized output feeds a series stabilizer TR1-4 which supplies the transmitter. In this stabilizer TR1 is a constant-current stage whose base potential is determined by the forward drop of the diodes D8 and D9. The transistor TR4 compares a fraction of the output voltage with the drop across the Zener diodes D11, D13. The difference between the collector currents of TR1 and TR4 supplies the emitter follower TR2 and hence TR3 which is the output transistor. This complete feedback loop gives an output of very low impedance and ripple. The diode D10 is normally cut-off but in the event of a transmitter fault demanding an abnormally high current, the drop across the collector load R7 causes diode D10 to conduct. This will reduce the current through TR1 and will cause the output voltage to collapse with only a small overcurrent.

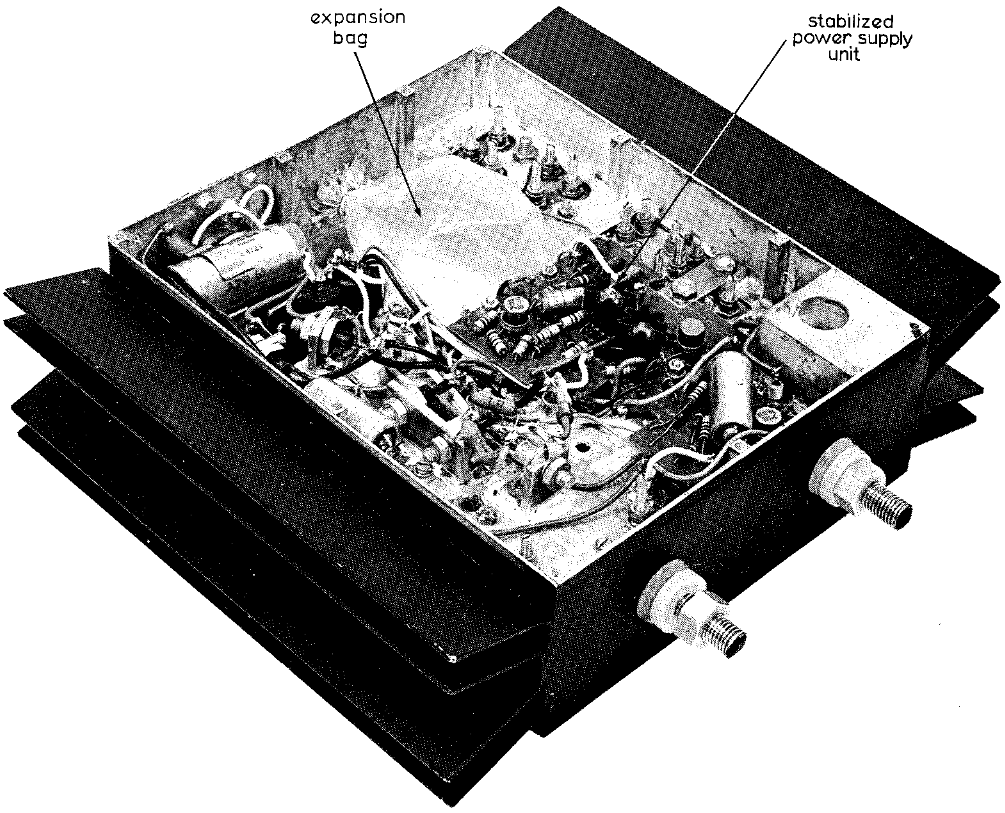
The frequency tolerance calls for a crystal oven, the heater of which is connected in parallel with the Zener diode D5. A constant current is drawn through these by the transistors TR5, TR6. When the oven reaches its operating temperature its internal thermostat disconnects the oven and the diode takes current in place of the oven load. This prevents any change in loading affecting the voltage on the balloon cable and hence unnecessary operation of the servo system.

4. THE TRANSMITTER

The circuit diagram of a 522 MHz transmitter is shown in Fig. 3 and photographs in Fig. 4.

The transmitter starts with a third overtone crystal oscillator at a frequency of 43·5 to 63 MHz dependent on the required final frequency. The crystal and oscillating transistor TR9 are in a small oven held at 75°C so that the transmitter frequency may be kept within tolerance. The output of the oscillator is amplified by the grounded-base stage TR10 before being frequency doubled by the varactor diode D21. A further grounded-base stage TR11 followed by two grounded-emitter stages TR12, TR13 bring the output up to 20 to 25 watts. This output supplies a balanced varactor tripler circuit which in turn drives a varactor doubler circuit.

The output of this doubler is monitored by the diode D25. Ideally an indication of forward and reflected power is desirable but circuit limitations imposed by the coaxial balloon cable ruled out the use of a directional coupler. With the diode circuit, the monitoring signal corresponds to output voltage and will only give an approximate indication of power because of the effect of aerial mismatch.



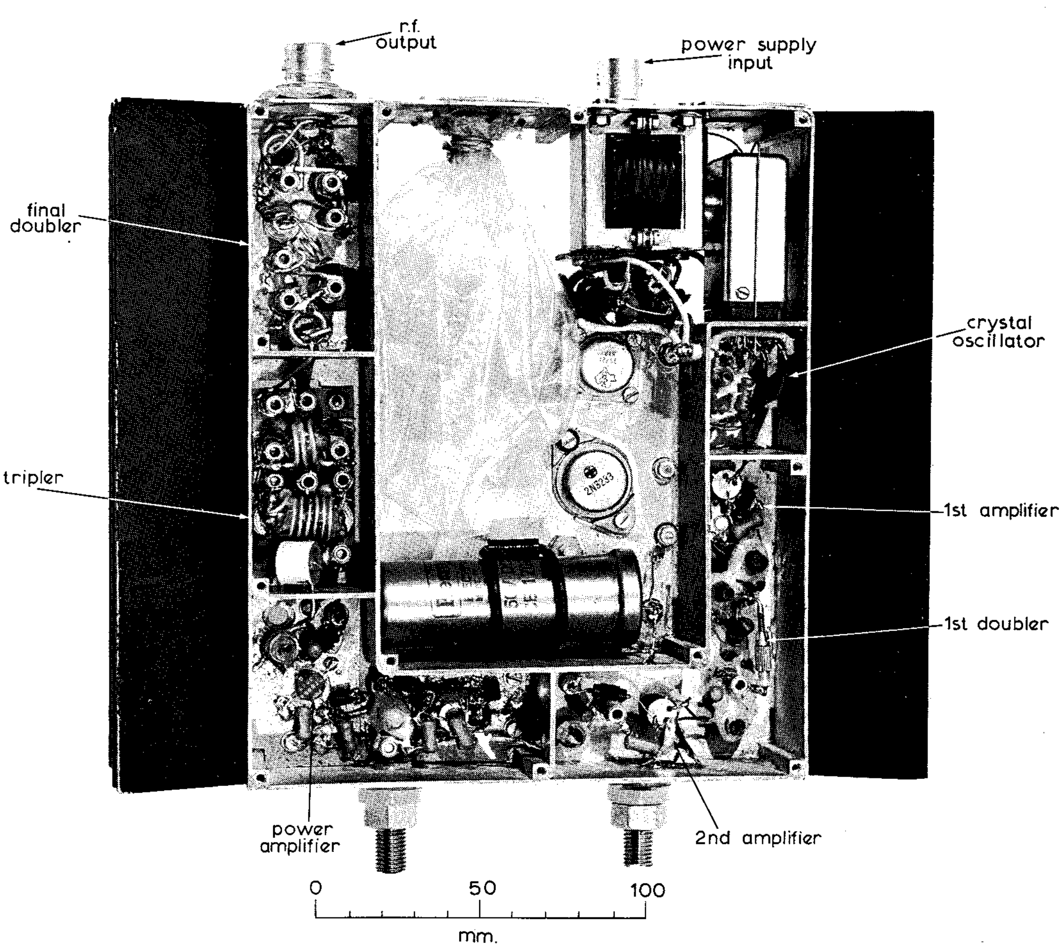


Fig. 4 - Photographs of transmitter

The system may also be affected by stray pick-up from a nearby transmitter or by unwanted components (see Section 6). It is, in any case, desirable to measure the power output into the aerial using a coupler type instrument and to check for unwanted components using a narrow-band receiver before and during the operational use of the transmitter.

The output is fed to the aerial via an interdigital filter, a photograph of which is shown in Fig. 5. It has four resonators flanked by matching lines and is designed for minimum loss (0·2 dB) at the carrier frequency and at least 20 dB of loss at the two frequencies spaced from the carrier by an amount equal to the crystal oscillator frequency.

5. MECHANICAL CONSTRUCTION

The transmitter is designed for easy attachment to either the balloon or a mast. Since the transmitter may be exposed to unfavourable weather conditions on the mast, it is necessary to seal it to prevent the ingress of moisture. Due to the lightweight construction, full hermetic sealing has been found impracticable. The transmitter is sealed as well as possible and a thin polythene expansion bag is provided. This avoids the pressure changes due to heating and cooling which tend to cause water or damp air to be sucked into the unit through any slight weakness in the sealing.

6. OVERALL PERFORMANCE

The outputs of the transmitters vary from 11 watts for the 522 MHz transmitter, falling to 7½ watts for the 756 MHz transmitter. The reduction in output is due to increases in varactor losses and reduction in power output from the final power amplifier at the higher frequencies. The overall efficiency of the transmitters from d.c. input to r.f. output is between 28% and 32%.

After an initial warm-up period of about 15 minutes the frequency stays within ± 2 kHz of the correct frequency over an ambient temperature range of + 45°C to - 10°C. This frequency variation includes an oven cycling variation of 150 to 750 Hz which is dependent on the particular oven thermostat. The power output from the transmitter normally varies by less than 0·5 dB over the above temperature range but as it falls off rapidly at higher temperatures it is advisable to mount the unit so that it is not in direct sunlight. At temperatures below - 10°C the varactor multipliers are liable to jump out of efficient multiplication and give rise to overheating of the power amplifier. A badly matched aerial (voltage standing-wave ratio less than 0·85) may also lead to this trouble.

The interdigital filter on the output keeps the level of all unwanted harmonics of the crystal oscillator below -60 dB relative to that of the wanted

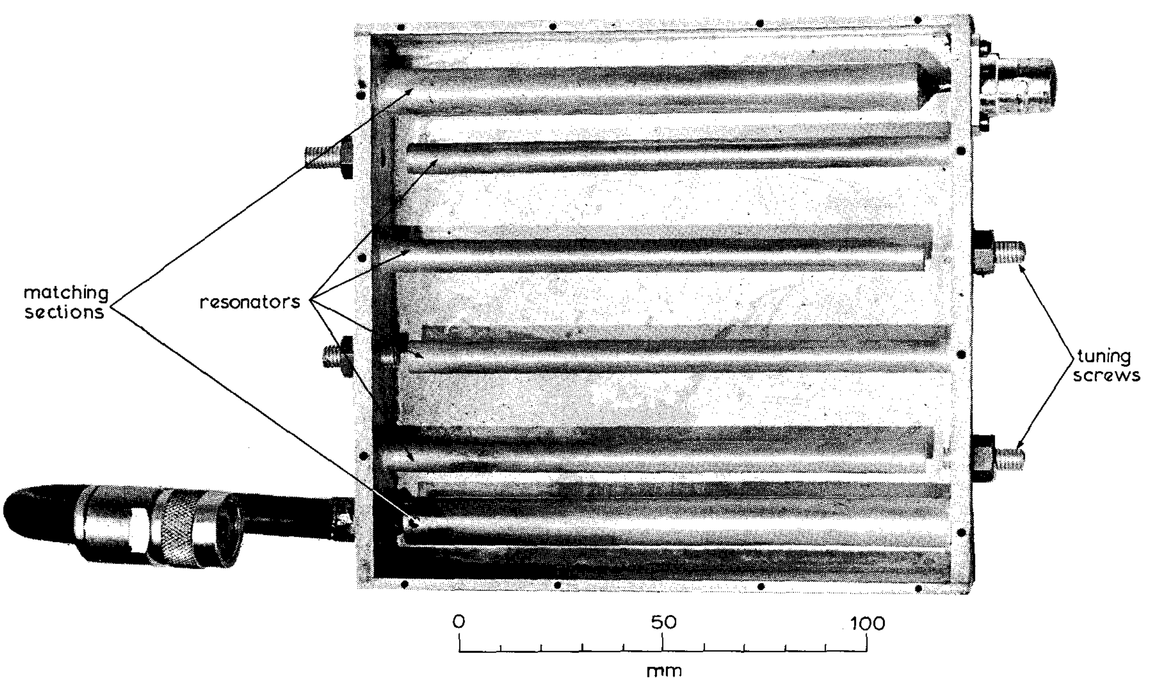


Fig. 5 - An interdigital output filter

frequency except in the case of the 522 MHz transmitter where only -40 dB has been achieved. A varactor multiplier may, however, give other unwanted components, including frequencies close to the main output frequency, in certain conditions of alignment, perhaps only over a limited temperature range. After any re-alignment, before releasing a transmitter for field work, it is therefore necessary to check the operation over the design range of ambient temperature, including a check that the unit will start up from cold.

There are certain aspects of the design of v.h.f. transistor amplifiers followed by varactor multipliers which are not fully understood. For example, a catastrophic failure of high efficiency power amplifiers can occur. It was at first thought that this was due entirely to a poor match causing the varactors to jump out of efficient multiplication and thereby reflecting power into the transistor which exceeded its power rating. It seems possible, however, that another mode of failure can occur with the power amplifier acting as a parametric amplifier for a considerably lower frequency, and causing an oscillation. This oscillation might build up very rapidly to a value considerably in excess of the voltage handling capacity of the transistor and so cause collector-to-base breakdown. Since reasonable precautions have been taken, the project does not warrant an investigation (which might involve the destruction of a considerable number of transistors) in order to clarify the failure mechanism.

7. REFERENCES

1. U.H.F. field strength measuring receivers. Research Department Report No. K-164, Serial No. 1963/43.

2. Variable capacitance diodes as frequency multipliers. Research Department Report No. G-094, Serial No. 1964/60.

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